

Does boiling spinach affect its oxalic acid content?

Chemistry Internal Assessment

Standard level

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Introduction

With all the quarantines going on within the past pandemic, it has become very common to hear about cases of anxiety rising more over in the populations of most countries, specially in teenagers. Anxiety is also known as the feeling of worry or nervousness typically about an imminent event or something we are not sure about the outcome, it is very common to experience occasional anxiety in our life, but this becomes a problem when this anxiety becomes repeatedly of episode of intense anxiety and interferes with daily activities not allowing the person to perform a normal life without constant worryness.

Having to spend my early teenage years across a global pandemic, it has become very common within my social circle to hear about classmates and friends to having developed anxiety disorders, in which in most cases even after the whole quarantines finished, they still happened to still be dealing with anxiety disorder, by not going out in social gatherings and being in constant worryness if in them. So in the search for helping them out, I came across with Magnesium (Mg), and I found out that Magnesium (Mg) helps a lot with overstimulation of the brain as it blocks the activity of more stimulating neurotransmitters and binds to calming receptors helping a lot with anxiety disorders. Only in the developed countries, Magnesium deficiency goes up to 20% of the total population (Flight, 2023).

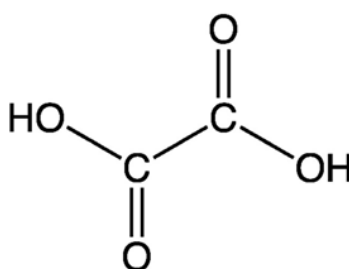
Taking magnesium pills would be a great idea for helping out people that are dealing with anxiety disorders (Anxiety Disorders - Symptoms and Causes, n.d.), but maybe these can be very expensive or the people can be simply not wanting to take the pill, thats why is important to look for foods that have a high magnesium content, and one example of a food that has a high magnesium content is spinach, with 79 mg of Magnesium for every 100 grams

of spinach. But there can be a problem with digesting all of the Magnesium as the oxalic acid ($C_2H_2O_4$) in the spinach happens to lower the absorption of the Magnesium (Richter, n.d.).

Oxalic Acid is thus an important factor affecting the absorption of Magnesium, present in Spinach as also in high magnesium content foods. Therefore, in the search for ways in which there could be a lower content of Oxalic Acid in Spinach, with the development of this Internal Assessment I will be investigating if the ways in which Spinach is cooked, in this case boiled, reduced its Oxalic Acid content.

Background Information

Oxalic acid is a dicarboxylic acid composed of the carboxylic acid groups of $HOOC$ and $COOH$, both polar because of its ability to form hydrogen bonds with water molecules. Its chemical formula is $C_2H_2O_4$, it is structured as two polymorphs, and when it reacts with water it becomes colorless because it's a white crystalline when it's solid. (*Oxalic Acid - Definition, Formula, Structure & Preparation - Chemistry*, n.d.)



The Structural formula of Oxalic acid

Oxalic acid is commonly found in potassium and calcium salt in the liquid of the vacuole of plant cells in numerous species of plants. When oxalic acid is under an aqueous solution, it becomes a weak acid that ionizes completely as it has two acidic protons.

During the absence of water, oxalic acid can exist in only two different polymorphs, in the first form, hydrogen bonding takes place, developing a chain-like structure in the intermolecular level; during the second polymorph, hydrogen bonding attributes a sheet-like structure to the compound. With this it can be deduced that Oxalic acid is hydrophilic, meaning that it seeks for water molecules.

Properties of Oxalic Acid

C ₂ H ₂ O ₄	Oxalic acid
Molecular weight/ Molar mass	90.03 g/mol
Density	1.90 g cm ⁻³
Appears	White crystals
Boiling point	365.1°C
Melting point	189 to 191 °C

Hypothesis

The result of this experiment and investigation will end up in the conclusion that boiling spinach does affect oxalic acid content.

Variables

Independent variable	Dependent variable
Cooking time of spinach (Min)	Volume of oxalic acid
0	
10	

Controlled variables

Controlled Variables	Reasoning	Method
Room temperature	Room temperature can affect rates of reactions or change solubility and more.	The temperature of the lab will be regulated and will be established at a consistent temperature.
Volume of acid in the distilled water solution	Acid should be added to water as pouring water to an acid form a concentrated solution that could boil very violently.	Acid should be poured to the distilled water solution.

Safety requirements and Environmental issues

Knowing that for the experiment I will be working with potassium permanganate and sulfuric acid, there are some safety precautions I must be aware of. According to the New Jersey department of Health and Senior Services, contact with Potassium permanganate can severely irritate skin and eyes, with possible eye damage. Breathing potassium permanganate can cause irritation on the lungs, nose and throat, causing coughs and shortness of breath

(Common Name: POTASSIUM PERMANGANATE HAZARD SUMMARY IDENTIFICATION REASON FOR CITATION HOW TO DETERMINE IF YOU ARE BEING EXPOSED, n.d.).

When working with sulfuric acid, sulfuric acid can cause skin irritation, redness, burns and blistering, and can cause severe burns with swelling and blurred vision when in contact with the eye. Therefore, by being aware of this, there must be eye and face protection, wear chemical safety goggles and face shield, with correct gloves, aprons and boots, and ventilation must take place in the place in which the chemical reaction is taking place.

Also, after the experiment was completed, all of the chemicals were given to the lab manager where she disposed of them safely. In the case of the sulfuric acid and the potassium permanganate, she dilutes them in water to obtain a final concentration of 1 M (98 g/l). Both of these final chemicals were kept in the lab incubator till disposing of them.

Experiment

Apparatus

1. Spinach 10 g
2. Pipettes
3. Erlenmeyer flask
4. Funnels
5. 25 ml vials
6. Titration equipment
7. Filter paper
8. Concentrated sulfuric acid 35 ml approx
9. Distilled water 50 ml
10. Potassium Permanganate 0.001N

Methodology

In order to do the following investigation, the following steps in which Oxalic acid in spinach before and after its cooked can be measured must be carried out:

First experiment with a variable of 5 min of boiled spinach.

- Weight 2 samples of spinach, in such an amount that after 12 hours at 105°C, 10 to 15 g of dry material of each sample can be obtained.
- Divide the fresh spinach into two portions, then boiled one of the portions with the respective variables (5 min and 10 min).
- Put the dry and boiled samples in an oven at 105°C FOR 12 hrs.
- Weight 10 to 15 grams of the dry sample, and incinerate. Temperature must gradually increase until it reaches 200 °C and there is no carbon left. Leave the sample in the

muffle furnace for about 2 hours at final temperature and then leave the sample to cool down.

- A portion needs to be added of 10 to 15 ml of sulfuric acid to the third to the sample.
- Filter with hot water, then add 20 ml of sulfuric acid to the third and 50 ml of distilled hot water.
- Titrate while hot with 0,001N potassium permanganate until the substance turns pink.
Right down values.
- Applied stoichiometry to find oxalic acid mass values.

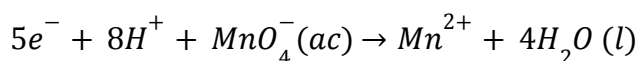
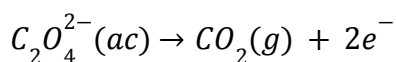
Data collecting

In order for a good production of data collecting and processing, I will first balance the redox reaction and list the raw data collected, which represents the relationship between spinach boiled at its oxalic acid content. Then, with the help of stoichiometry formulae, it will be estimated if a change in the oxalic acid content occurs after boiling in spinach, and then a relationship will be established if that change were to occur.

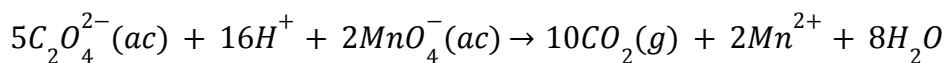
Redox reaction

By using half reactions, I have a general method to balance the redox equations of the relation between the ion permanganate, MnO_4^- , and the oxalate ion, $C_2O_4^{2-}$, in an acidic solution. When $C_2O_4^{2-}$ is added to MnO_4^- , the intense purple color disappears. CO_2 bubbles form and the solution becomes a pale pink color from the Mn^{2+} . H^+ is consumed and H_2O is produced. This can be deduced from the balanced reaction.

First, the equation will be divided into two half incomplete reactions, one for oxidation and the other for reduction.



From here, I balance each half reaction and add them and it gave the following reaction:



Raw data

Boiling time of spinach ($\pm 0,01$ s)			Difference of solution of oxalic acid in burette reading ($\pm 0,05$ ml)		
Tiral 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
0	0	0	83	79	88
10	10	10	9	11	10

Uncertainty

To make sure there are low levels of uncertainty, some steps were taken in order to mitigate the margin of error. Some of these steps involved: Reading the Burette at eye position level with the surface of the liquid to have a proper reading of the volume.

To calculate uncertainty, the uncertainties of all the materials were listed and then sum with each uncertainty of each trial. The uncertainty of the burette was $\pm 0,05$ ml for the 20 ml burette. Therefore, for every trial, a $\pm 0,05$ ml uncertainty will be added to each trial.

Table of Propagation of error

	Trial 1	Trial 2	Trial 3
Oxalic acid in unboiled spinach	$\frac{0,05}{83} \times 100 = 0,06\%$	$\frac{0,05}{79} \times 100 = 0,06\%$	$\frac{0,05}{88} \times 100 = 0,05\%$
Oxalic acid in boiled spinach	$\frac{0,05}{9} \times 100 = 0,5\%$	$\frac{0,05}{11} \times 100 = 0,4\%$	$\frac{0,05}{10} \times 100 = 0,5\%$

Data processing

First, the values registered for the difference of oxalic acid in reading the burette will be taken as L, therefore the conversion of ml to L must take place.

$$\frac{83}{1} \times \frac{1L}{1000\text{ ml}} = 0,083L \quad \frac{79}{1} \times \frac{1L}{1000\text{ ml}} = 0,079L \quad \frac{88}{1} \times \frac{1L}{1000\text{ ml}} = 0,088L$$

$$\frac{9}{1} \times \frac{1L}{1000\text{ ml}} = 0,009L \quad \frac{11}{1} \times \frac{1L}{1000\text{ ml}} = 0,011L \quad \frac{10}{1} \times \frac{1L}{1000\text{ ml}} = 0,010L$$

For applying stoichiometry formulae, the average of the values obtained of Trial 1,2 and 3 will be used. Therefore, average of the difference of solution of oxalic acid in burette registered are:

For unboiled spinach:

$$\frac{0,083+0,079+0,088}{3} = 0,083\text{ L}$$

For 10 minutes boiled spinach:

$$\frac{0,09+0,011+0,010}{3} = 0,010\text{ L}$$

Once the average of the difference of solution of oxalic acid in burette was calculated. The mass of oxalic acid in spinach can be calculated.

To find out the mass of oxalic acid in **unboiled spinach**, I did the following:

- 1) By knowing the difference of oxalic acid in volume that was read in the burette till the reaction went to completion, and by also having the value of the concentration of oxalic acid, I found out the number of moles.

$$n = CV$$

$$n = 6,320 \times 10^{-03} \frac{\text{mol}}{\text{L}} \times 0,083 \text{ L}$$

$$n = 5,23164557 \times 10^{-04} \text{ mol}$$

- 2) From here, with this data, using the following formula the mass of oxalic acid per 10 grams of unboiled spinach was calculated.

$$n = \frac{m}{Mr}$$

$$5,25 \times 10^{-04} \text{ mol} = \frac{m(g)}{158 (\frac{g}{\text{mol}})}$$

$$5,25 \times 10^{-04} \text{ mol} \times 158 (\frac{g}{\text{mol}}) = m(g)$$

$$5,25 \times 10^{-04} \text{ mol} \times 158 (\frac{g}{\text{mol}}) = 0,083 \text{ g}$$

Therefore, the amount of grams of oxalic acid in 10 g of unboiled spinach is 0,083g.

$$\frac{0,083 \text{ g of oxalic acid}}{10 \text{ g of spinach}}$$

To find out the mass of oxalic acid in **10 minutes boiled spinach**, I did the following:

- 1) By knowing the difference of oxalic acid in volume that was read in the burette till the reaction went to completion, and by also having the value of the concentration of oxalic acid, we can find out the number of moles.

$$n = CV$$

$$n = 6,320 \times 10^{-03} \frac{\text{mol}}{\text{L}} \times 0,01 \text{ L}$$

$$n = 6,329 \times 10^{-05} \text{ mol}$$

- 2) From here, with this data, using the following formula the mass of oxalic acid per 10 grams of 10 minutes boiled spinach can be calculated.

$$n = \frac{m}{Mr}$$

$$6,329 \times 10^{-05} \text{ mol} = \frac{m(g)}{158 (\frac{g}{\text{mol}})}$$

$$6,329 \times 10^{-05} \text{ mol} \times 158 (\frac{g}{\text{mol}}) = m(g)$$

$$6,329 \times 10^{-05} \text{ mol} \times 158 (\frac{g}{\text{mol}}) = 0,01 \text{ g}$$

Therefore, the amount of grams of oxalic acid in 10 g of 10 minutes boiled spinach is 0,01g.

$$\frac{0,01 \text{ g of oxalic acid}}{10 \text{ g of spinach}}$$

Difference between the values of the oxalic acid obtained from the unboiled and boiled spinach is:

$$0,083 - 0,01 = 0,073 \text{ g}$$

Data analysis and conclusion

The results of the mass in grams of oxalic acid in 10 grams of spinach that were boiled for 10 minutes and the ones that weren't present a noticeable difference. With the average values of the oxalic acid obtained from the boiled and unboiled, a difference of 0,073 g was calculated, showing that boiling spinach has a huge impact on the oxalic acid content of the spinach.

This result helps to prove my hypothesis that boiling spinach does affect oxalic acid content in it. When calculating uncertainty, the values obtained for the table of propagation of uncertainties were very low, with percentages of uncertainties being minimal, which allow me to state that the work done in this investigation was precise and efficient.

This investigation has given a solution to my interest about how eating boiled spinach will help get better absorption of nutrients like magnesium which therefore has a positive impact on mental health. So now, after doing this experiment, I feel like I could be of so much help to those who are battling with their mental health by having more knowledge on ways this can be reduced and now I could be of good news to those who are looking for some, which left me really inspiring.

Evaluation

I believe the work done in this investigation was very good and optimal as a hypothesis surge, and therefore from that hypothesis a whole investigation where an experiment was held, and the learning from the subject were employed. This eventually concluded with that hypothesis being proven, which was a great learning process to the course.

Errors and improvements

Systematic error

As it was complicated to have access to an oven which could have a high enough capacity, a systematic error could have emerged as the samples were incinerated for a longer time but at a lower temperature, which could have an impact on the result of the grams of the samples obtained. But anyways, this was done to both, unboiled and boiled spinach so the difference is still the same.

Random error

No random error has been spotted for this work. Although some readings could differ but the precautions of eye position being at the surface level of the liquid were taken place so random errors diminished.

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